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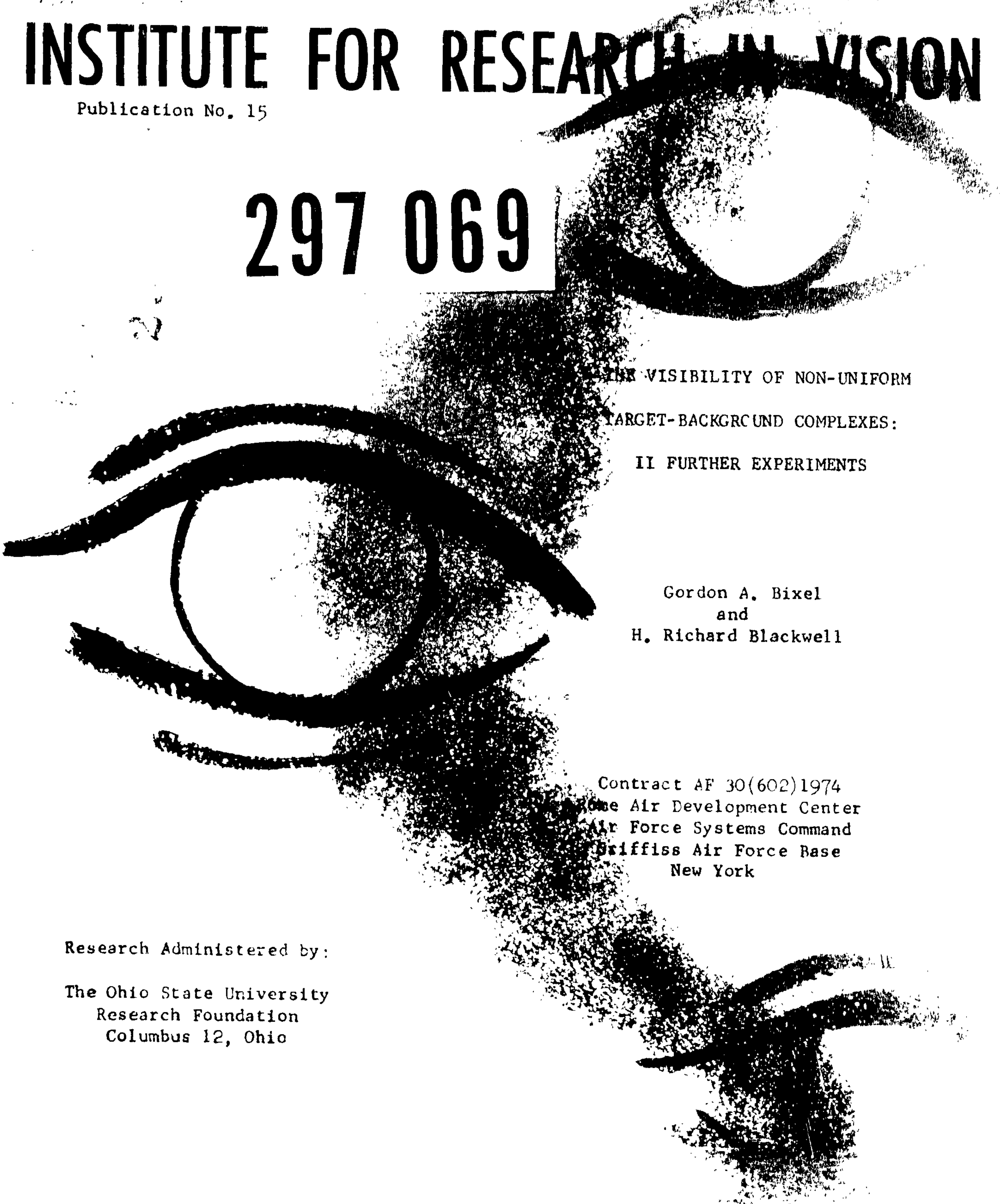

THE VISIBILITY OF NON-UNIFORM TARGET-BACKGROUND COMPLEXES: II FURTHER EXPERIMENTS

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FOREWORD

The research reported herein has been carried out under the sponsorship of the Human Engineering Laboratory, Rome Air Development Center, United States Air Force, under Project 8501.

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ABSTRACT

Further studies have been made of targets of uniform luminance presented against backgrounds of non-uniform luminance. The backgrounds consisted of an array of ball-bearings painted gray, which produced a regular pattern of luminance non-uniformity, each element of which subtended 8 minutes of arc. Targets were circles measuring 4, 8, and 24 minutes in diameter which were superimposed over the background, thus obscuring it over their area. Experiments were conducted in which the overall contrast of the target-background complex was systematically varied until the target was at the visibility threshold. In various experiments, the target was varied in its contrast with regard to the non-uniform background. Comparison experiments were always conducted in which a background of uniform luminance was used.

When the visibility of the targets was considered described by their luminance with respect to the average luminance of the background, the visibility thresholds of targets presented against non-uniform backgrounds differed from those of targets presented against uniform backgrounds in a complex manner which differed as a function of target size. However, when the visibility of the targets was considered described by their luminance with respect to the luminance of the immediately adjacent elements of the background, visibility thresholds were the same for targets presented against uniform and non-uniform backgrounds. This implies that visibility thresholds are determined by target contrast at target borders rather than by some kind of average contrast.

Similar results were obtained at exposure durations of 1.9 and 0.1 seconds.

I. INTRODUCTION

The present is the second report of a series of experiments concerned with the visibility of target-background complexes of non-uniform luminance. These experiments have been found to be most difficult to conduct due to the near impossibility of achieving a satisfactory method of production of target and background stimuli for threshold study.

The first report contained some very preliminary studies utilizing a method of adjustment and some preliminary studies utilizing a method of constant stimuli. Although data were reported in the earlier report, we were generally dissatisfied with the method used to present the stimulus material, which consisted of the alternate presentation of positive transparencies, one of which contained a background alone, the other of which contained a target and a background.

The present report summarizes results obtained with a new method of stimulus presentation with which we are reasonably well satisfied. Now that the serious problem of stimulus production has been solved, we hope to begin to develop a reasonable understanding of the visibility of these complex targets.

The method of constant stimuli used for this experimentation requires that each of a number of "stimuli", varying in difficulty, be presented repeatedly and the probability of some discriminatory response determined for each stimulus difficulty. In the present problem the difficulty of the stimulus material was altered by superimposing some particular amount of veiling luminance over the entire target-background complex. The overall luminance of the target-background complex was maintained constant by reducing the light coming from the stimulus complex in direct proportion to the amount of light veil added to reduce overall contrast.

The discriminatory problem presented to the observer was to identify which one of four temporal intervals in a sequence contained a target-background complex, the other three containing the same background complex without the target. The forced-choice method of Blackwell (Ref. 1) was utilized, since this method has been shown (Ref. 2) to possess greater validity and reliability than the more usual method involving direct subjective appraisal of the presence or absence of discrimination. The use of the best possible methodology is of particular importance in the present problem, since the judgement that a target can be just seen in a target-background complex is not a simple one for an observer to make.

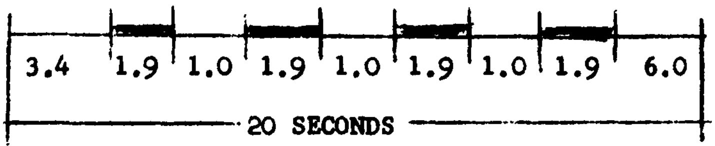
The major problem with the forced-choice method is that the observer can discriminate the target from the non-target on any basis available to him. In order for the data to be meaningful, the experimenter must be assured that the observer is making his discriminations on a basis known to the experimenter and intended by him to be the experimental variable. Eliminating all differences between the target-background complex and the background alone except the presence or absence of the target is a formidable undertaking.

This problem had been encountered in previous experimentation (Ref. 3). A number of changes were made in the method of presenting the target-background complex that considerably reduced these difficulties. These will be explained subsequently.

II. APPARATUS AND PROCEDURES

The experiments were conducted in a room 12 ft. wide, 12 ft, long, and 8 ft. high with an 8 by 20 ft. extension on the back to accommodate the new target presentation apparatus. This room was divided by a wall into two portions with the observer on one side and the apparatus on the other. Schematic drawings of the experimental set-up are shown in Figures 1, 2 and 3, and the essential distances are shown in Figure 4. The observer sat on one side of a wall. Through an aperture in the wall he was able to see a white uniform surround measuring 11 by 14 inches and located 14.75 inches from his eye. Thus, the surround subtended about 36° in the vertical direction and 43° in the horizontal direction. The surround was illuminated by four lights on the side of the wall opposite from the observer's station, located at a radial distance of 6 inches from the center of the wall. The luminance of the surround was about 360 foot-Lamberts. In the center of this surround there was a 1 1/2 inch diameter round hole covered from behind by a shutter of the same white material as the surround. Opening this shutter exposed a real image of the stimulus complex, located in the same plane as the surround. The image of the stimulus complex subtended 5 degrees and 49 minutes.

The shutter, operated by a solenoid, created the following presentation cycle:



The stimulus presentations are shown in heavy lines. Numbers indicate time in seconds. During three of the four stimulus presentations, the background complex was exposed. The target was added to the background complex during one of the four presentation intervals selected at random, and the observer was asked to select which of the four presentations was the stimulus complex containing the target. In case no target was seen, the observer was asked to select and record the one of the four most likely to have been the stimulus complex containing the target. The observer recorded his selection by depressing one of four buttons mounted near his hand; this recorded correct or incorrect answers on suitable electric counters.

The targets were matte white circles subtending 4, 8 and 24 minutes of arc respectively. These targets correspond in size to the 1/4, 1/2 and 1 1/2 inch targets used in the previous experiment (Ref. 3).

The uniform background consisted of a flat grey surface 2 ft. square. The non-uniform background, also 2 ft. square, consisted of row upon row of ball bearings, each of which subtended 8 minutes of arc. These balls were set in a plastic material with the upper half of each ball extending above the level of the plastic. The balls and plastic were painted a neutral grey and appeared to the observer as a background of relatively bright areas on the face of each ball, receding to darker areas between the balls. Figure 5 shows a 24 minute target against the non-uniform background.

The background was placed 19 ft. 4 3/4 inches from Lens L3 (see Figure 4), which is the distance necessary to obtain the desired angular size. At this distance, the image of each ball of the non-uniform background subtended 8 minutes of arc. The background was illuminated by a 4 ft. square, 30 inch deep box containing twenty 100 watt light bulbs and painted white inside. The background was held close to a 2 ft. circular opening in the back of this box (see Fig. 3) and was illuminated by the light in the box. The observer views the background through an opening in the front of the box which was just large enough (19 3/4 inches) to allow him to see the 2 ft. circle of background exposed through the opening in the back of the box.

The target was placed in front of the light box so that it could be illuminated by a separate source of light which would not fall directly on the background. This was done so that the target would not cast a shadow on the background. Experimentation with the target placed as close as possible to the background had revealed some conditions where the shadow created by the target provided a false cue of greater magnitude than the target itself.

The target was illuminated by two 500-watt projectors. Each projector was aimed at the target from an angle of 45 degrees from the plane of the target. Each projector was on a ramp, one above the target and the other below. The ramps were designed so that the projectors could be moved along the ramps, changing the intensity of illumination on the target. The 45 degree angle was sufficient to prevent direct illumination of the background.

The target was suspended on two thin wires, 0.004 inch in diameter. Each wire, aided by pulleys, formed a loop encircling the light box and background. Behind the background there was a lever arm activated by a pneumatic cylinder. This lever arm attached to the two wires could quickly move the wires back and forth along the track of the pulley. Thereby, the target, also attached to these wires, could be quickly placed in or removed from the observer's view. The device was very accurate in positioning the target. Consecutive presentation of the small targets varied less than 1/32 inch.

Lens L3 formed an image of the target-background complex in the plane of the surround which was located 14.75 inches from the observer's eye. The plane of the surround was presumably conjugate with the observer's retina so that he obtained an in-focus view of the target-background complex.

Reduction in contrast was accomplished by adding veiling light and reducing the light from the stimulus complex so that the combined light intensity from the two remained constant. There were two separate systems for reducing stimulus intensity and adding veiling light, the "wheel" filters and the fixed filters, as shown in Figure 2.

A. The Wheel Filters

The stimulus intensity was reduced by filter wheel 1. The wheel contains five separate filters, any one of which could be placed in the light path by manipulation of a control switch which rotated the wheel into the desired position. The relative transmittances of the filters were as follows: position 1, 100%; 2, 75%; 3, 60%; 4, 47%; and 5, 17%. Veiling light was added from lamp La 1 at the top of Figure 2. The beam labeled SV travelled through filter wheel 2 and filter holder F4. Filter wheels 1 and 2 were mechanically linked so that a position of one always implied a given position of the other. These two filter wheels were so balanced that the resultant total light intensity remained approximately constant, e.g. position 1 allowed the maximum light through from the stimulus material and a minimum of veiling light, while position 5 allowed the minimum light from the stimulus material and a maximum veiling light.

B. The Fixed Filters

The other source of veiling light (labeled V in Fig. 2) came through filter holder F3 and was added to the main beam by beam-splitter BS1. The V beam formed an image of lamp La 1 about 2 inches in front of the observer's eye. Though this was not a true Maxwellian system, it was adequate to provide the necessary intensity and uniformity of illumination of veiling light. The contrast of the stimulus material was reduced by adding filters to holder F1 while the same time removing filters from F3 such that the total light intensity remained constant. This was the method used to adjust the contrast to the threshold range of each observer for each target-background complex, and these filters were not changed until the observer had completed all the sessions on a given target. The contrast was varied within the threshold range by means of the previously mentioned filter wheels.

The filter holders F2 and F4 were used to balance the light intensities from the various beams and were frequently readjusted. Filters were put in holder F4 to equalize the intensity of veiling beam SV with the intensity of the beam containing the stimulus material. For this balance, the filter wheels were put in the position of maximum transmittance. Filters were used in holder F2 to equalize the intensity of veiling beam V with the total of the SV beam and the beam containing the stimulus complex. For this balance, it was necessary to use an ND.3 filter in F3. This could later be removed in steps as filters were added to F1 and the total luminance maintained approximately constant.

An additional loss in contrast was found to result from the four surround lights. Part of this light was reflected by Lens L1 into the observer's eye. This light was measured and included in the determination of the contrast.

Initially three student observers were used. However, one observer was forced to discontinue his observing because of academic difficulties. The results shown in this study are for the remaining two observers: RL, a 22 year old white male, and AL, a 21 year old white male.

Both observers were uncorrected and appeared to have normal vision as tested with the Titmus Optical Co. Vision Tester.

Neither observer used any optical aids during his observing. The motivation of the observers seemed to be adequate throughout the entire series of tests.

It is directly meaningful to define the "contrast rendition" of the optical system for any given combination of filters in the filter holders and the filter wheels. It is also meaningful to define the physical contrast of the target when the background is of uniform luminance. It is not directly meaningful to define physical contrast when the background is of non-uniform luminance. However, it is necessary to refer to the physical "contrasts" of the targets with the non-uniform background. This contrast will be obtained by using the average luminance of the background. The contrast presented to the observer by the target-background complex viewed through the optical substitution apparatus is the product of the physical contrast of the target with its background and the contrast rendition of the device. Our calculations of contrast values for the targets with uniform and non-uniform backgrounds were complex and laborious and may be described as follows:

A. Contrast of the target

Measuring the contrast of the target involves comparing its luminance with the luminance of its background according to the following formula, first used by Blackwell (Ref. 4):

$$C = \left| \frac{B_T - B_B}{B_B} \right| \tag{1}$$

where C = contrast
B_T = luminance of the target
B_B = luminance of the background

All measurements of target contrast were made from the observer's position with a photomultiplier photometer designed by our late colleague, B. S. Pritchard.* This was done so that the final contrast values would reflect any losses that might occur in the optical system. The surround lights and lamp La 1, whose contribution to the reduction of contrast are discussed elsewhere, were turned off during this measurement.

The 0.1 degree aperture was used in the photometer to measure the relative target luminance. Even this opening was too large for the 4 minute target and it was necessary to place a large piece of target material in the target position for this measurement.

The 0.1 degree aperture was too small to integrate a representative portion of the non-uniform background. Therefore, the 1 degree photometer aperture was used to obtain the average luminance of the background. When measuring contrast we therefore temporarily inserted a large uniform surface and first compared its luminance with the luminance of the background using the larger aperture and then compared its luminance with that of the target using the smaller aperture. Using a modification of equation (1), the contrast becomes:

$$C = \underbrace{\frac{B_T}{B_{cB}}}_{\text{0.1 degree aperture}} \times \underbrace{\frac{B_{cB}}{B_B}}_{\text{1 degree aperture}} - 1 \qquad (2)$$

where B_T = relative luminance of the target
B_{cB} = relative luminance of the large uniform surface
B_B = relative luminance of the background

In order to insure uniformity of the measurement procedure, this same system was also used with the uniform backgrounds.

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*Marketed as the Spectra Pritchard Photometer by the Photo Research Corporation 837 North Cahuenga Blvd., Hollywood 38, California.

B. Contrast rendition of the filter wheels.

The transmittances of the five filter wheel positions have been given previously.

Contrast rendition was computed from the relation:

$$CR = \frac{S}{S + SV} \tag{3}$$

where CR = contrast rendition;
S = relative intensity of the beam containing the stimulus complex as modified by filters in filter wheel 1; and
SV = relative intensity of the SV beam as modified by filters in filter wheel 2;

The contrast rendition values were as follows:

Wheel Position	Contrast Rendition
1	.814
2	.606
3	.478
4	.398
5	.149

C. Contrast rendition of filters in holders F1 and F3.

Contrast rendition was computed from the relation:

$$CR = \frac{(S + SV)}{(S + SV) + V} \tag{4}$$

where S = relative intensity of the beam containing the stimulus complex as modified by filters in filter holder F1 for wheel filter position 1;
SV = relative intensity of the SV beam as modified by filters in filter holder F1 for wheel filter position 1; and
V = relative intensity of the V beam as modified by filters in filter holder F3.

The luminance of the target background as viewed by the observer was measured with the Pritchard photometer each time the target, background or a projector bulb was changed.

During each session 50 presentations were made at each position of the filter wheels. There were blocks of 10 consecutive presentations at each wheel position with the order of the various wheel positions randomized.

III. RESULTS AND DISCUSSION

The raw data consisted of the target contrast as modified by the contrast rendition of the apparatus for each of the 5 wheel positions, and the number of correct responses at each position. These data were analyzed by a probit analysis performed on the IBM 704 computer and are plotted in the accompanying graphs as the 50 percent probability contrast. This probit method follows in general the method of Kincaid and Blackwell (Ref. 5).

The experiments were performed under the following conditions:

1. The targets used were white circles of 4, 8 and 24 minutes of arc.
2. The backgrounds used were:
    a. a uniform grey surface
    b. the non-uniform surface composed of ball bearings

In the case of the non-uniform background each target was centered directly over one of the bright elements (balls) of the background. The duration of exposure was 1.9 seconds.

In each of the accompanying graphs, the 50% threshold contrast is the ordinate and the abscissa is the physical contrast of the target. This means, first, the higher the point on the graph, the more difficult it was to see; second, the closer the point is to the left border of the graph, the less the amount of the physical contrast of the target before the light veil was added. Targets of initially low contrast appear in backgrounds of initially fixed internal contrast differences from element to element. Thus, variations in the physical contrast, modify the relative target-background contrast with respect to the internal contrasts within the background itself. The threshold contrast as mentioned earlier is computed from the physical contrast of the target and the contrast rendition of the instrument. As the physical contrast is reduced (moving toward the left of the graph), a lesser reduction of contrast is required from the instrument. This makes the elements of the non-uniform background more visible and their effect on the target visibility more pronounced. The 50% threshold of the visibility of the elements of the background is represented by the center one of the three short vertical lines along the bottom of the graph. It is labeled M. Our experimental set-up did not permit us to use the non-uniform background in the target position, and determine the visibility of its elements per se in the usual manner. We therefore mounted a large circular target subtending 149 minutes of arc in the target position, and used it to simulate the uniform background in the central fixation area. Its luminance was made equal to the average luminance of the non-uniform background against which it was seen in one of the four target presentation intervals. The presence or absence of this target was detected by the observer noting the presence or absence of the non-uniformity in the central fixation area. By this means we found the threshold of visibility of the elements of the background to equal 0.00856 on the average for the two observers.

In the instance of the 4 minute circular target* (Fig. 6), the non-uniformity of the background progressively reduces the visibility of the target as it becomes more visible that is, as the initial physical contrast of the target is reduced. With the 24 minute target (Fig. 7), the non-uniform background is shown to have the opposite effect. The non-uniform background seems to have no demonstrable effect upon the visibility of the 8-minute target (Fig. 8).

In explanation of this seemingly contradictory effect, we would like to offer a theory in which the visibility of the target is based to a considerable extent upon the maximum contrast along its border.

To understand the different border contrasts produced by the non-uniform background, it will be helpful to examine briefly the light distribution of the

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*For the 4 minute target, it was found necessary to reduce the background luminance from 360 foot-Lamberts to 170 foot-Lamberts to achieve greater target-background contrast.

background. The illumination provided by the light box is uniform. However, a much greater portion of it falls on the projecting convex hemisphere of each ball bearing than falls on the recessed area between the ball bearings. As would be expected, the luminance of the ball bearing background is maximum at the highest point on each ball and minimum in the area between the balls. The relative luminance was measured across a number of the ball bearings with the Pritchard photometer with the results shown in Fig. 9.

There is a small variation in the readings of similar areas of different balls. This is likely caused by (1) actual differences in the luminances of these similar areas due to irregularities in the non-uniform background and (2) inaccuracies in the measurement of the luminance. These differences are considered negligible.

It should be noted that the supra-threshold level of visibility of the elements of the non-uniform background increases or decreases as the rendition of contrast by the experimental apparatus is increased or decreased.

Figure 10 shows the position of each of the three targets used with respect to the balls. From this it can easily be seen that the 4 minute target falls entirely within one of the balls of the non-uniform background. The luminance of the background immediately adjacent to the border of the target is greater than the average background luminance, and therefore the local contrast with the brighter target is less than the contrast computed on the basis of the average background luminance. If the contrast is actually less than the value assumed, the target will seem to be more difficult than it really is. This effect will be expected to increase as the elements of the background become more visible. That this in fact occurred is demonstrated by the experimental results shown in Figure 6.

One would expect no significant difference between the target visibility using the uniform and non-uniform background if the luminance of the non-uniform background were taken to be that at the border of the target. This was done and the recomputed data for the four minute target are shown in Figure 11. It will be noted that the data points in the graph no longer show diminishing target visibility as the visibility of the background is increased.

The theory of maximum border contrast can also be used to explain the enhancement of visibility that is found in the instance of the 24 minute target. The position of the target is shown in Figure 10. Fifty-eight percent of the border of this circular target lies adjacent to the darker area between the balls of the background. The contrast along this portion of the border is greater than the contrast when the average background luminance is used. Therefore, one would expect the target to increase in visibility as the elements of the background are made more visible. The results plotted in Figure 7 show this to have occurred.

The same data were replotted using the greater contrast occurring between the target and the darker portion of the background. These results are presented in Figure 12 and show that with this interpretation of contrast, the visibility of the non-uniform background has no systematic effect on the visibility of the target.

The non-uniform ball bearing board background was not found to have a systematic effect on the visibility of the 8 minute target (see Fig. 8). Inspection of the target position (see Fig. 10) shows the target to completely cover one of the balls. This places the entire border in an area of the background which is of less than average luminance. However none of the target border falls in the area of minimum background luminance, that is, the central area between any set of 4 balls and maximally distance from any of them. (See Figs. 9 and 10) Therefore, at no point is the maximum contrast with the background obtained. Thus, the position of the 8 minute target results in too small a difference between the average and the local contrast to produce a measurable effect when the initial physical contrast is altered.

It should be noted that the experimentation became increasingly more difficult as the target-background contrast was reduced to progressively lower levels. Increasing the contrast rendition of the apparatus, which was necessary to make the low contrast targets visible, also increased the effect of false cues such as a difference in color of target and background.

A. Shortened Exposure Duration

The effect of a shortened exposure duration was investigated briefly by reducing the exposure duration from 1.9 seconds to 0.1 seconds and obtaining six data points. The physical contrast of the target was reduced to a low level to insure a high degree of visibility of the elements of the non-uniform background and increase their effect on the visibility of the target.

Four of these points, two with the uniform background, and two with the non-uniform background were taken using the 4 minute circular target, and are shown in Figure 13. Also shown in Figure 13 is the curve for the 1.9 second exposure duration, adjusted to best fit. It should be noted that while the short exposure increased the difficulty of detection with both the uniform and the non-uniform backgrounds, their relationship remained generally the same. As with the longer exposure, the 4 minute target remained more difficult to see against the non-uniform background than against the uniform.

One pair of points was taken with the 0.1 second exposure using the 24 minute target. These points are shown in Figure 14 together with the curve for the longer exposure for the 24 minute target, adjusted to best fit. Here again the short exposure increased the difficulty of detection of the target against both uniform and non-uniform backgrounds. Here again their relative visibility remained the same as for the longer exposure time.

The results with the 4 and the 24 minute targets indicate that shortening the exposure duration increased the difficulty of detection with either the uniform or the non-uniform background by approximately similar amounts.

It is difficult to reconcile the results found in the present experimentation with those reported in the previous experiments on this problem (see Ref. 3). Using targets of similar size, the previous report indicated that non-uniform background increased the difficulty of target detection for all three target sizes by approximately equal amounts.

An optical substitution apparatus was used in the earlier experimentation. Instead of viewing an image of the actual target and background as was done in the present experiment, the observer viewed an image created by a photographic transparency of either the background alone, or the background with the target in place. The reader is directed to the above mentioned report for further description of the experimental procedure.

Review of the previous experimentation reveals a number of differences in the stimulus complex as follows:

1. The photographic reporduction of the target reduced the sharpness of the border. This would be expected to reduce any effect produced by contrast at the border.

2. A difference in the illumination of the non-uniform background created secondary areas of higher intensity in the background used in the earlier work in place of the darkest areas of the present non-uniform background.

The painted ball bearing board was similar in the two cases. In this present study, it was illuminated by a light box which effectively gave it non-directional illumination since the angle of illumination varied from near parallel to the background to within 20 degrees of normal to the background. It does not, however, provide any illumination within 20 degrees of the normal. This results in a higher background luminance on the higher portion of the balls and dark areas between the balls. In the earlier experiments, the transparencies were made with all of the illumination normal to the background. The luminance of the elements of the background depended upon the angle formed with the direction of the illumination. Those parts of the background normal to the direction of the illumination were most luminous. They were the high portions or centers of each ball, as in the present experiment. But they also included the very lowest area formed by the material between the balls, which, in the present experiment, formed the darkest elements. This elimination of the areas of highest contrast could in part explain the failure of the previous experiments to produce enhancement of the 24 minute target by the non-uniform background.

3. Inadequate attention was paid to the centering of targets. This results in having the border of the target adjacent to variable parts of the background. According to the theory of border contrast offered herein, this would confound the results.

The threshold obtained for targets presented against a uniform background is approximately the same in the two studies. In the present study the visibility of the background elements was systematically varied from the extreme of high visibility to invisibility, with the target always being brighter than the background. In last year's study, two separate targets were used for each of the three target sizes. One was brighter and the other darker than the background. The visibility of the elements of the background was determined by the rendition of contrast necessary to bring the target to the threshold of visibility. Comparing this rendition of contrast with the threshold for the elements of the background found in the present study, one finds a contrast rendition greater than threshold in each of the three instances where the target was darker than the background and also in one of the three cases where the target was brighter than the background. The final target visibility was similar regardless of whether the target was brighter or darker than the background, and in each case the threshold was considerably higher (target less visible) than in the control experiment with the uniform background. If the visibility of the elements of the background was similar to that in the present study, this would indicate that the presence of the non-uniformity had a deleterious effect on the visibility of the target whether or not this non-uniformity was visible. This conclusion the authors are not prepared to accept and it is in fact not confirmed by the present study. These results could be partially explained by some consistent error in measuring the physical target contrast in the case of the non-uniform background; however, re-examination of the method of determining contrast revealed no such error.

None of the above reasoning offers an adequate explanation for the overall deleterious effect on target visibility found to be produced by the non-uniform background in the earlier experiments, so that some uncertainty must remain in our interpretation of the earlier data, since there is every reason to believe that the methods utilized in collecting the data reported herein are definitely superior to those utilized in the earlier experiments.

It is interesting to consider the effects of background non-uniformity in terms of the element contribution theory of spatial effects within the visual system recently postulated by Kincaid, Blackwell, and Kristofferson (Ref. 6). This theory was derived from data on the detection threshold, and refers of course to the spatial interactive effects believed to occur from point to point within the area of a stimulus which is at the threshold for detection. If the notion were carried over directly to background elements each of which is definitely above threshold, we would expect the effects of different spatial elements of the background to occur across spatial extents of the order of 30 minutes of arc or more. Our results indicate that the effective area of the background is quite close to the target. In the instance of the 4 minute target whose threshold seemed to be influenced primarily by a lowered border contrast, areas of maximum contrast with the background were only 3.7 minutes away. Nevertheless, the effect of the low contrast border formed with the immediately adjacent portion of the background was what we measured so that any counter effects produced by the high contrast 3.7 minutes from the border could not have produced a significant effect. In the case of the 8 minute target, areas of maximum contrast were only 1.7 minutes away. The immediate contrast was but little greater than the average contrast and our results suggested that target visibility was not dependent upon the areas of maximum contrast even though they were only 1.7 minutes removed from the target border.

It is perhaps worth noting that this experiment has been restricted to an investigation of the visibility threshold of a target against various backgrounds looked at in a localized context. The experiment does not investigate the possible loss in the ability of an observer to locate a target which may result from the presence of a non-uniform background. In this experiment we attempted to avoid this problem by assisting the observer in locating the target. There remains, therefore, the possibility that non-uniformity of background luminance will affect detection under operational circumstances in a manner different from the results of our study.

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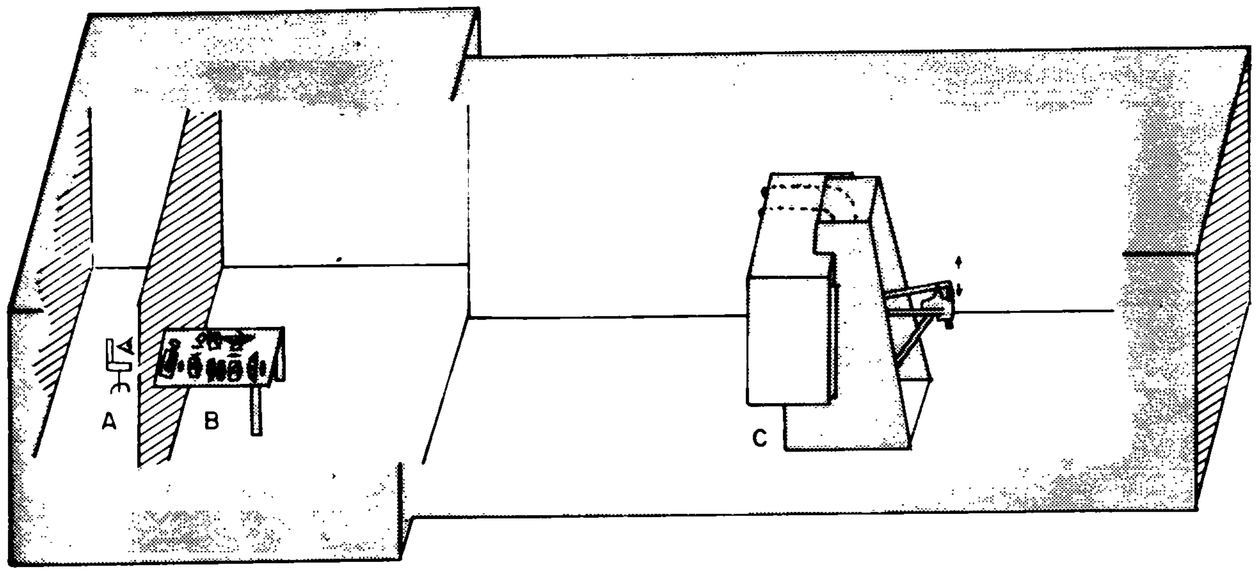

Fig. 1. Cutaway diagram of room used for experimentation showing

- A. Position of observer
- B. Table for contrast reduction apparatus
- C. Support for
  1. The background
  2. The light box that illuminates the background
  3. The target and the apparatus for moving it in and out of view.

GA 3602

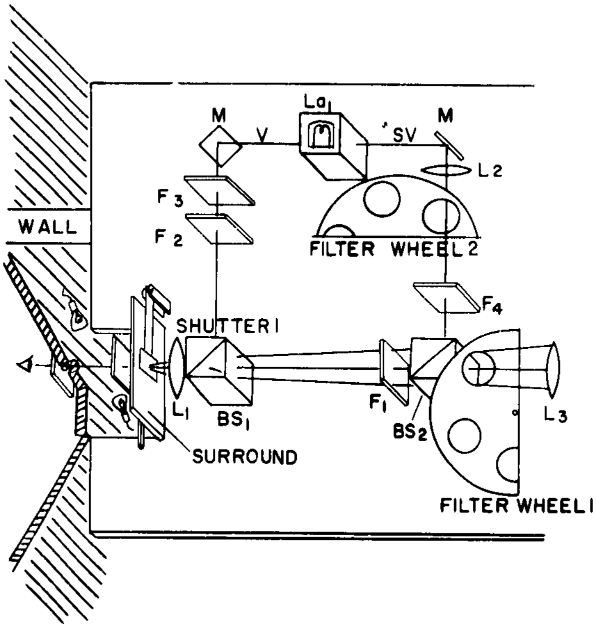

Fig. 2. Diagram of Contrast Reduction Apparatus

La_1 - Illumination Source
M - Mirror
F - Filter holder
BS - Beam Splitter
L - Lens
SV, V } - Veiling light beams

See text for description of operation.

GA 3603

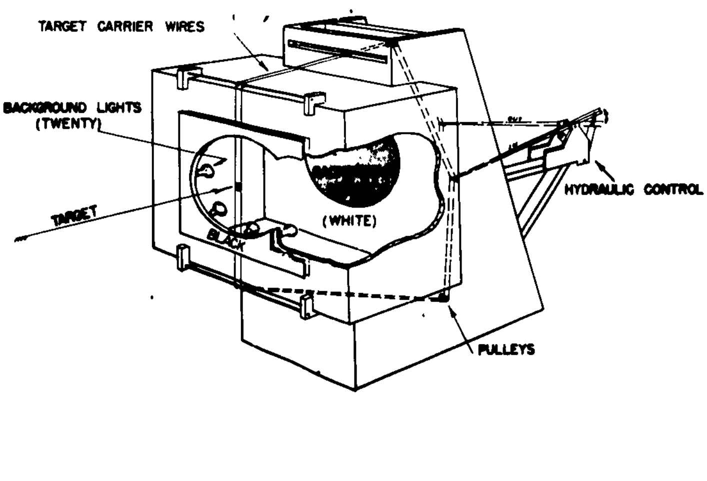

Fig. 3. Cutaway diagram showing illumination of background and system for placing target in and out of observer's view.

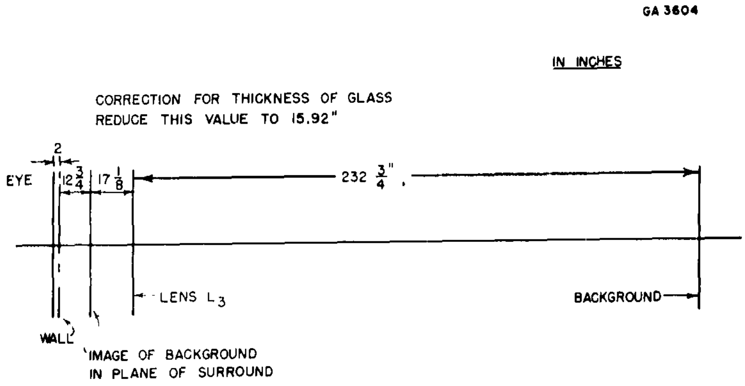

Fig. 4. Diagram of essential optical elements that form the image.

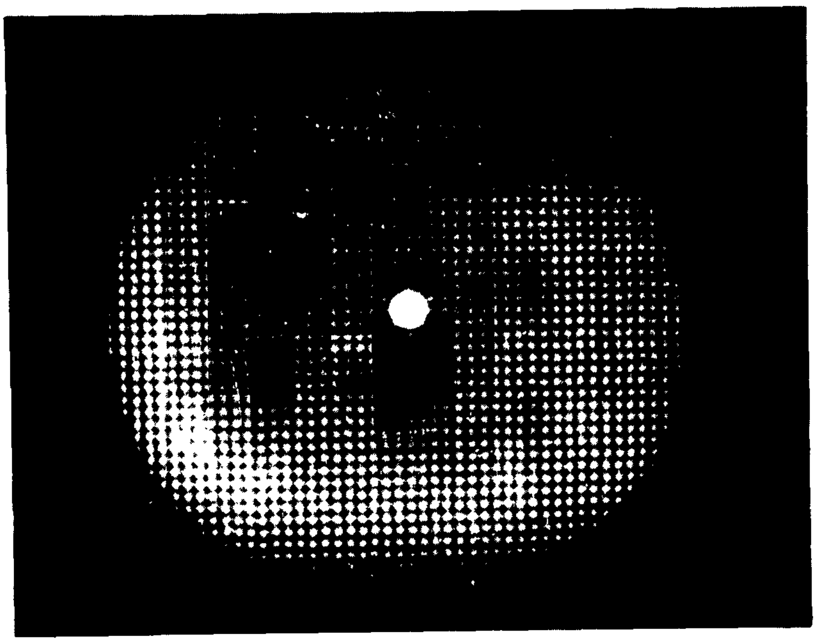

Fig. 5. A picture of the 24 minute target against the non-uniform background.

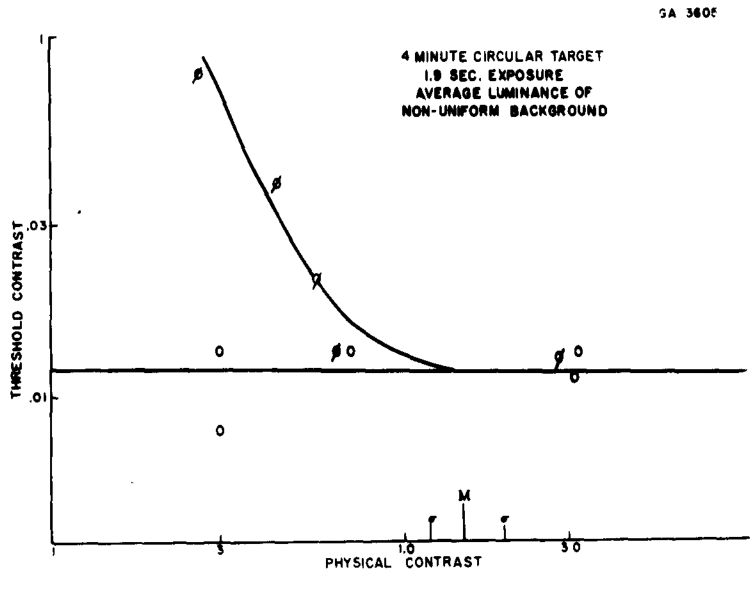

Fig. 6. O Target against uniform background
Ø Target against non-uniform background
M Threshold of visibility of the elements of the non-uniform background

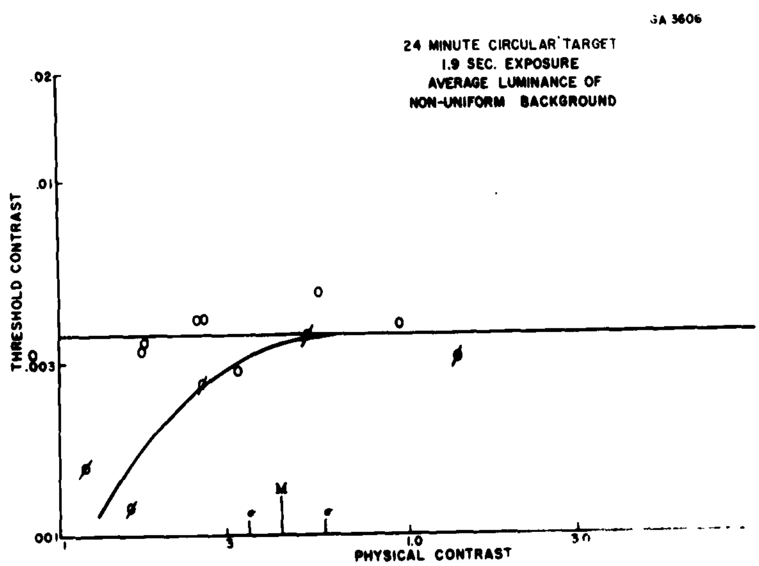

Fig. 7. O Target against uniform background
Ø Target against non-uniform background
M Threshold of visibility of the elements of the non-uniform background

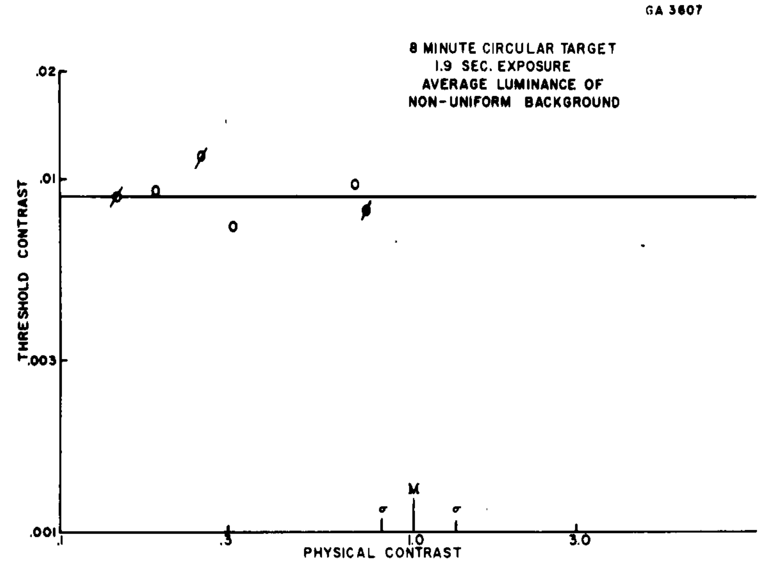

Fig. 8. O Target against uniform background
Ø Target against non-uniform background
M Threshold of visibility of the elements of the non-uniform background.

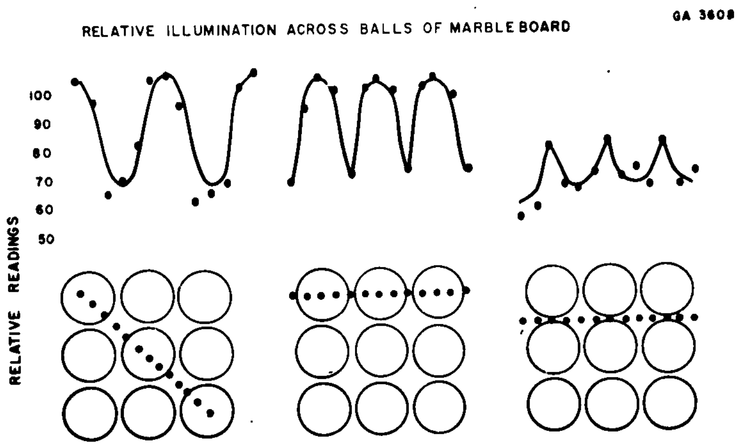

Fig. 9. Relative illumination across spherical elements of non-uniform background. Relative luminance readings were made using 0.1 degree aperture of Pritchard photometer and placing instrument directly in front of light box. Each solid circle in line of small circles in lower figure of circles represents approximate area covered by each photometer reading. Position of graph above represents its relative luminance.

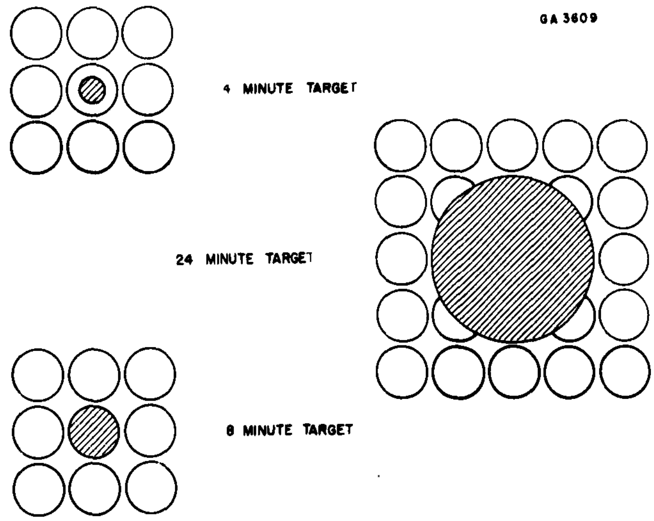

Fig. 10. Illustration showing position of each target relative to elements of background.

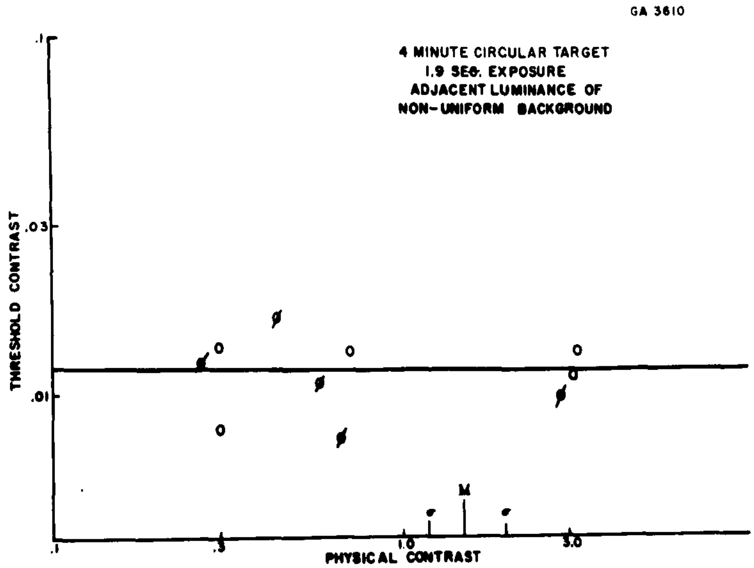

Fig. 11. O Target against uniform background
Ø Target against non-uniform background
M Threshold of visibility of elements of non-uniform background

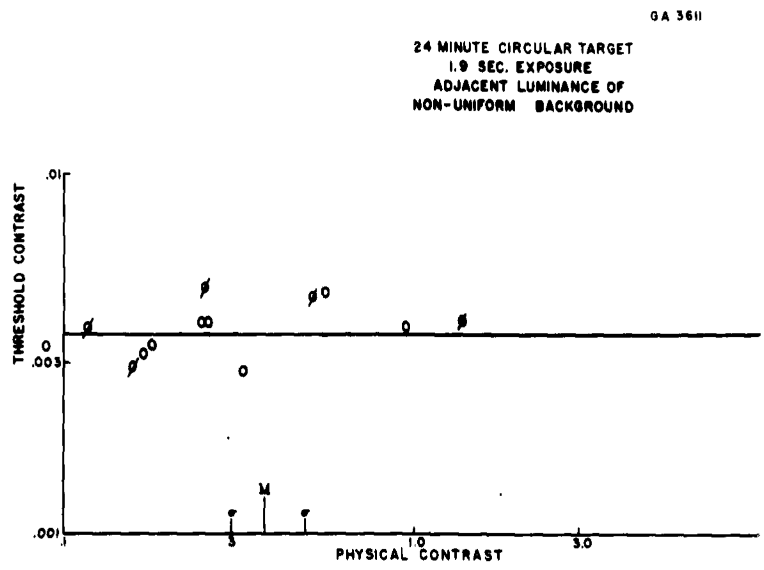

Fig. 12. O Target against uniform background
Ø Target against non-uniform background
M Threshold of visibility of elements of non-uniform background.

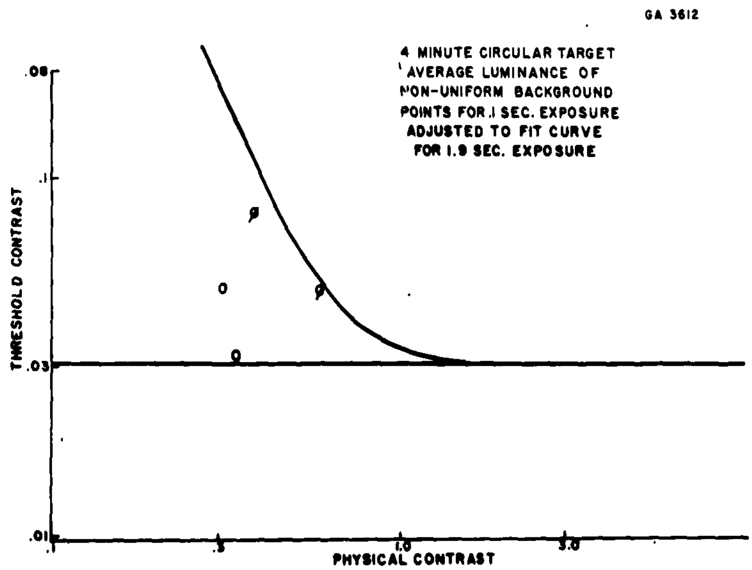

Fig. 13. O Target against uniform background
Ø Target against non-uniform background

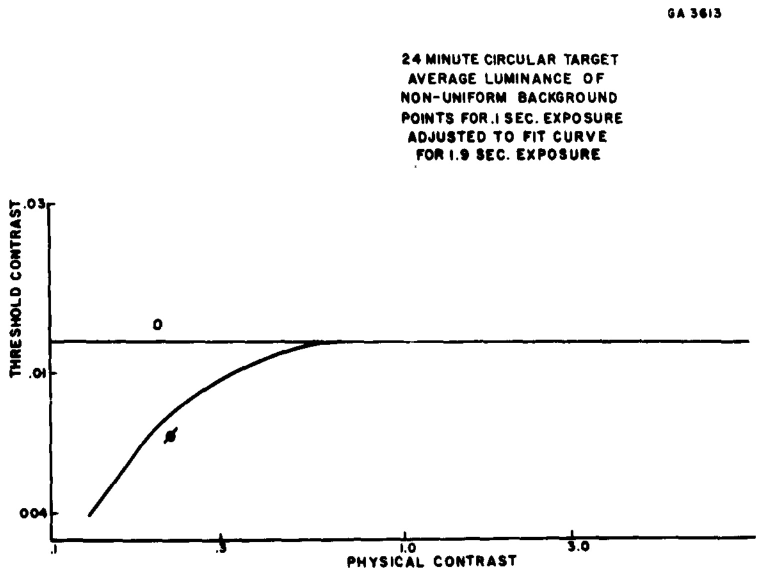

Fig. 14. **0 Target against uniform background**
Ø Target against non-uniform background